NEW HAMPSHIRE

DROUGHT MANAGEMENT PLAN

PREPARED BY:
DEPARTMENT OF ENVIRONMENTAL SERVICES
NEW HAMPSHIRE WATER RESOURCES DIVISION

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TABLE OF CONTENTS

PREFACE

This Drought Management Plan is the seventh and final draft in a process, which has been developing since early in 1985. The 1985 drought experienced in the South Eastern United States raised concern that New Hampshire may face a drought. As is usually the case, the fear of imminent drought precipitates action. With the concurrence of the Governors Office, the then Water Resources Board began researching the many aspects of a successful state response to drought conditions. The Water Resource Division has continued the planning process through snowy winters and spring floods because the next drought is inevitable. The plan presented was drawn in part from the experiences and plans of other states. A drought management conference sponsored by South Carolina in 1986 was an invaluable source of insight into planning, implementation and pitfalls offered by those who had a plan in place and had the need to use it.

This document provides guidance. It has been revised subsequent to input from a Task Force of varied special interests. The critique and modification have refined this valuable tool, which is both general enough for statewide application and capable of addressing significant issues of local concern.

ACKNOWLEDGEMENT

Appreciation is offered to the many people who assisted in the review and modification of numerous drafts contributing their technical expertise and personal insight to reflect the broad range of interests effected by drought. Many representatives of the following organizations contributed towards this product.

NH Dept of Environmental Services
NH Office of State Planning
NH Office of Emergency Management
NH Dept of Health
NH Dept of Resources & Economic Development
NH Fish & Game Dept
NH Public Utilities Commission
NH Dept of Agriculture
NH State Climatologist
NH Association of Conservation Districts
Office of the Speaker of the House
Office of the President of the Senate
US Geological Survey
National Weather Service
University of NH
NH Water Works Association
Hampton Water Works
Manchester Water Works
NH Municipal Association
Town of Milford
City of Berlin
Business & Industry Association of NH
Monadnock Paper Mills
W.R. Grace Co
Public Service Co of NH
The state of South Carolina
The state of New York

NEW HAMPSHIRE DROUGHT MANAGEMENT PLAN

I. INTRODUCTION

This drought management plan is divided into three sections to facilitate presentation and understanding. These sections are Administration, Detection / Monitoring and Response. The functioning plan involves the exchange of information between sections and open communication between the various responsible parties.

Discussion among the multidisciplinary Task Force, which enhanced this plan, revealed a broad underlying belief that although drought is a physical, quantifiable occurrence, appropriate response to the prevailing condition is an economic, social and political action. This interaction between the scientific and social aspects of drought calls for a broad understanding and sensitive analyses of potential impacts. Individuals with both experience and public trust will play the delicate role of balancing the public good with individual sacrifice.

1. PURPOSE AND SCOPE

The purpose of the drought response plan is to insure that New Hampshire will respond in an organized, responsive and appropriate manner in the event of a drought related water shortage.

Although the plan includes procedures for monitoring selected climatic, water-supply and water-use data as a means of determining the potential for drought to occur or to continue, it should not be construed as an attempt to predict the occurrence or end of a drought. The plan provides a basis for both generating and supporting management decisions related to the use and, if necessary, the allocation of water during periods of varying drought conditions.

One fundamental concept of the plan is that major responsibilities rest with the public water suppliers. Water system capabilities and reserves are highly variable and therefore localized responses must be appropriate for the specific system. The local drought response plan should be an integral part of a general emergency response program because of the numerous similarities in response for various situations.

The role of the state is primarily one of coordination, information dissemination and, if necessary, mobilization of personnel and equipment in response to emergencies.

Drought conditions may exist simultaneously over several states or be confined to a small area or areas within a single state. Likewise, the severity or effects of a drought may vary considerably due to a variety of factors, such as unequal distribution of rainfall, differences in topography and soil, varying drainage patterns and differing geologic formations. To accommodate these factors and to facilitate drought management assessment and response, New Hampshire has been divided into Drought Management Areas (DMAs, Appendix C). Variations in drought severity may still occur within these management areas, but they represent a reasonable and cost effective compromise in terms of desired geographic area, data availability and existing capabilities. The management of the state's water resources as outlined in the drought response plan will require legislative support, inter-agency coordination and cooperation, improved data gathering and creative methods of modeling and analysis.

2. HISTORICAL OCCURRENCES OF DROUGHT IN NEW HAMPSHIRE

Although New Hampshire is generally blessed with abundant rainfall, which is evenly distributed throughout the year, droughts of varying magnitudes have occurred with their associated hardships to man and his activities. The changing nature of the state economy leads to different impacts from extended drought. The original agrarian economy would sustain major crop and livestock losses from the combined impacts of lack of rainfall and excessive heat. The industrialized economy of the 1800's was highly dependent upon river flow to power mills and rainfall to fill the water supply reservoirs. The present economy includes the historic water uses for agriculture and water power as well as an ever increasing need for water to serve not only the domestic needs of the growing population but the industrial and commercial needs of a growing economy. Because of the great variety of water needs within the state and the potential impacts of prolonged drought, a plan is needed to assist the many water using sectors in dealing with the inevitability of a recurring problem.

Droughts have been recurring through the past centuries. Normal precipitation for New Hampshire averages 40 inches per year. A search of precipitation records of this century revealed three years with less than 30 inches of precipitation. Although a 25% reduction in precipitation does not seem severe, this level of deficit has only occurred three times within this century. Most people cannot remember the drought of 1914 while some may remember the drought of 1941. The 1964-65 drought was recent enough that many people remember the emergency response measures, which were initiated.

The large recurrence interval of these events points to the need for an established plan, which can be activated when the need arises. As long as the Water Resource Division, the U.S. Weather Bureau and U.S. Geological Survey monitor hydrologic conditions, New Hampshire will be capable of assessing the need for implementing a planned response to the next inevitable drought.

Monthly and seasonal variations from normal are expected and are not considered rare or regional enough to warrant statewide response. Precipitation data from the State Climatologist for the Northern Region of N.H. is presented in the Appendix to offer insight into 'normal variability". Data on the duration of droughts is presented in the Appendix, which shows that very few droughts have lasted longer than 9 months.

3. AUTHORITY

The primary source of authority for implementing drought response rests with the Governor's Emergency Powers under RSA 107-C:4. This statute creates the Emergency Management Agency, which has broad authority in all forms of emergencies. Auxiliary authority exists under other jurisdictions for responses specific to that jurisdiction.

The Department of Environmental Services Water Resources Division has authority under RSA 482:2 to direct dam owners to store or release waters in response to emergencies where the public health or safety may be jeopardized.

The Department of Environmental Services Water Supply and Pollution Control Division has the authority under RSA 148:22 to require public water suppliers to develop drought contingency plans for their particular system.

The Public Utilities Commission has authority, which can be exercised relative to the operation and management of utilities in times of emergencies.

Local governing bodies including cities, town and village districts have numerous powers which can be exercised to protect the public health and welfare.

The U.S. Army Corps of Engineers has authority to modify the mode of operation of their network of flood control reservoirs to lessen the impacts of drought on streamflows.

II. ADMINISTRATION

Primary responsibility for establishment and implementation of the Drought Management Plan rests with one of the three Administrative units described below. (Task Force, Drought Management Team, Executive Committee) Participants in the Drought Management Team may have additional responsibilities in other components of the plan. The three administrative units will function individually at different times throughout the development and implementation of the plan.

1. TASK FORCE

A task force has been established with the discreet responsibility of establishing the final drought management plan. Broad representation by groups and individuals with experience and expertise in the many facets of hydrologic monitoring, water use and administration insured the development of a plan, which accomplishes established objectives. The task force received administrative support from the Water Resources Division and was responsible for establishing the following components of the plan:

a. Identification of agencies and/or people with the experience, jurisdiction and authority to perform specific functions.

b. Establish drought management areas. (See Appendix C)

c. Establish the detection and monitoring plan.

d. Establish the response plan.

Once the plan was established, the task force was disbanded and transferred responsibility to the Drought Management Team or its Executive Committee.

Membership on the task force was extended to a very broad representation. The task force was then divided into functional working groups to focus expertise and foster greater efficiency. Specific representatives on the task force are listed in the Acknowledgement.

TASK FORCE MEMBERSHIP

GOVERNOR'S OFFICE
Office of State Planning
Emergency Management
Agency

DEPT. OF ENVIRONMENTAL SERVICES
Water Resources Division
Water Supply and Pollution
Control Division

Also

Dept. of Resources & Economic Development
Dept. of Health, Division of Public Health Services
U.S. Weather Bureau
President of the Senate

Dept. of Agriculture
Fish and Game Dept.
Public Utilities Commission
U.S. Geological Survey
Speaker of the House

REPRESENTATIVES OF THE FOLLOWING INTEREST GROUPS:

Public Water Supplier
Municipal Supplier
Private Supplier
Industry -
Industry Regional Planning Agencies

Agriculture
Power Production
Cities and/or Towns
Light Industry Soil Conservation Districts Heavy

2. DROUGHT MANAGEMENT TEAM

The DMT is the group of people representing agencies and water interests, which has the responsibility for implementing the appropriate response for drought events. The composition of the DMT was established by the Task Force and is listed below. The team will be convened when needed as determined by the Executive Committee.

The representatives on the DMT will confirm the existence and level of the drought. Information on appropriate responses will be distributed by these representatives through existing communication networks to the water users. Input from the water users to the DMT will be channeled through these representatives.

It should be noted that the Office of State Planning and the Office of Emergency Management have organizational networks, which facilitate communication with the municipalities through the Regional Planning Commissions and the Area Representative respectively.

Drought Management Team

Governor's Office
- Office of Emergency Management
- Office of State Planning

Dept. of Environmental Services
- Water Resources Division
- Water Supply and Pollution Control Division

Dept. of Agriculture
Dept. of Health - Division of Public Health Services
Dept. of Resources & Economic Development
N.H. Municipal Association
N.H. Water Works Association
N.H. Business & Industry Association

3. EXECUTIVE COMMITTEE

The executive committee will consist of selected representatives who are members of the DMT. The committee has the responsibility of insuring that ongoing monitoring of hydrologic conditions is proceeding. The committee reviews monitoring reports provided by advisory agencies such as the U.S. Weather Bureau and Geological Survey and determines when it is appropriate to issue drought notices, and to convene the DMT in response to prevailing conditions and to meet the needs of certain water users.

The Executive Committee will be composed of the following individuals representing their agencies:

Director of Emergency Management
Director of State Planning
Commissioner of Environmental Services
Director of Water Resource Division
Director of Water Supply and Pollution Control Division

III. DETECTION/MONITORING

One essential component of the drought management plan is the determination of the percentage of normal hydrologic values at which a certain stage of drought response should be initiated. The percent of normal can relate to storage reservoirs, stream flow, groundwater level, soil moisture and precipitation. Various threshold values were developed for the several stages of drought response. Development of the threshold values should be a multidisciplined effort, which evaluates the frequency, distribution, severity and duration of historic drought occurrences.

A subgroup of the Task Force with specialized knowledge of hydrology met to establish threshold values. There was consensus that specific values are necessary for administrative purposes in implementing response. There was also consensus that the prevailing hydrologic conditions at the time of the meeting (March 27, 1989) were severe enough to warrant issuance of a drought alert. The alert being the first phase of response which is primarily an advisory. Beyond this, the group was unable to specify hydrologic limits for particular drought stages. The scientists in effect deferred to the administrators and appointed officials to establish specific criteria. This is consistent with the belief that social and economic impacts must be considered along with environmental impacts.

Section four of this part of the plan presents threshold values developed by the Department of Environmental Services and generally concurred with by the task force. They are not hard and fast limits but guidance values to be considered by the drought management team in declaring a specific drought stage.

1. IMPACT

The potential impact of a drought is a function of the severity of deficient precipitation and the duration of the deficit. The type of impacts will vary according to the magnitude of the two factors (severity, duration). Different interests will be impacted in different ways and at different times. Responses by particular interests are described fully in the section on drought response.

The severity and duration of a drought will create an impact of a certain magnitude. Four magnitudes of drought are presented to assist in measuring the appropriate level of response:

Level	1	Alert	(incipient)
Level	2	Warning	(moderate)
Level	3	Emergency	(severe)
Level	4	Disaster	(extreme)

The descriptions used above are those used by New York State and South Carolina. Section 4, which follows, presents a means of determining drought impact levels in New Hampshire. It remains an obligation of the drought management team to declare the existence of a specific level of drought.

2. SEVERITY

Severity is the measure of the amount of moisture deficiency. This term can be expressed as a measured amount, a percent of normal or a recurrence interval for a certain condition. The latter form of expression requires historic record of considerable length which may not exist for certain measurements. The measured amount or percent of normal approaches therefore represent more realistic methods of estimating drought severity.

Various expressions of water (moisture) availability should be considered because potential impacts are dependent upon the nature of the deficit.

a. Stream Flow - Stream flow is of critical importance for water supply, waste assimilation, power production, ecological sustenance and recreation purposes. Measurements of stream flow have been made at fixed locations for various periods of record up to 50 years. The records of stream flow have been statistically analyzed and frequency of recurrence intervals exist for most stations. A map showing the location of stream gauging stations largely unaffected by flow regulation and representative of large geographic areas is presented in the Appendix.

b. Precipitation - Precipitation deficits have an immediate impact on agriculture and a long term impact on reservoir levels, stream flow and groundwater levels. A network of precipitation recording stations has existed for many years and historic data is available. Existing and historic monthly average values are available for each county from the national weather service. Because lack of precipitation triggers all forms of drought, evaluation of precipitation events is of vital concern.

c. Soil Moisture - Soil moisture levels are a function of precipitation, transpiration, soil type, temperature and wind. Deficits in soil moisture directly impact agricultural production and indirectly impact other water availability when extensive irrigation is required. The Palmer Drought Severity index is a measure of soil moisture, which includes the time effect of deficient precipitation. The Palmer index cannot be used in the winter months because of frozen ground. A description of how Palmer index values are determined is included in the Appendix.

d. Ground Water Levels - Variations in ground water levels occur seasonally during normal weather. Long-term precipitation deficits limit the amount of recharge, which in turn contributes to declining water tables. Lowered water tables directly impact water supply well yields and contribute to reduced stream flows. Groundwater is the hydrologic element, which responds slowest to precipitation deficit but is also the slowest to recover from prolonged drought. Because of the effect of pumping, local aquifer analysis is needed in addition to regional assessment. Both the U.S. Geological Survey and public water suppliers gather periodic data on groundwater levels.

e. Forest Moisture - The majority of New Hampshire's land area is forested which places potential forest fire conditions at a relatively high priority. Forest fire conditions increase and decrease at an extremely rapid rate when compared to other hydrologic factors. The primary measure of fire conditions is the moisture content of detritus on the forest floor. Forest fire danger ratings vary independently from the broader drought stages indicated on this plan. Both the U.S. Forest Service and the N.H. DRED Division of Forests and Lands have systems in place to assess forest fire danger levels.

f. Reservoir Levels - The many storage reservoirs throughout New Hampshire serve a multitude of purposes, which have shifted through the past 150 years. Certain historic uses persist at some locations while the changing nature of the states industrial and economic base has altered the primary functions of other reservoirs. Present uses include: Water supply, water storage for flow augmentation and hydropower production, and recreational use. Reservoir levels are as much a function of the flow management strategy as the inflow from the watershed.

Water demand dictates operation of many impoundments while watershed characteristics greatly influence the response of a reservoir to decreased inflow or increased withdrawals. Because of the correlation between management practices, specific needs, and watershed characteristics, drought management of reservoirs must be viewed as a site-specific evaluation and operation requirement. Each reservoir operator should have a "rule curve" as a basis for comparing present conditions to a long-term average. The rule curve shows optimum water level management and is bracketed by curves for moderate, severe, and extreme drought conditions. Site-specific guidelines determine appropriate operations under the varying drought conditions. A sample rule curve is provided in the Appendix. The range of potential actions is discussed in the response section of this plan. In general, response is based upon an evaluation of present storage, projected demand and expected inflow.

3. DURATION

The duration of deficient precipitation must be coupled with the magnitude of the deficiency to assess the impact upon different water uses. Data on the duration of historic drought events is included in the appendix.

a. Short Term -(less than three months).

Short Term drought is a fairly common occurrence in New Hampshire. Generally speaking, short-term drought will have a focused impact upon a particular group of water users. When the timing of a short-term drought corresponds with the growing season, the impacts can be severe upon the agricultural community. When it occurs during mid -winter, the impacts are felt by the skiing industry.

Short-term drought is also significant as an indicator of potentially longer drought and greater impacts. Precipitation deficits have a cumulative effect so they must be closely monitored.

b. Medium Term -(up to 9 months).

The cumulative effect of deficient precipitation over several seasons creates a situation of significant concern to many water use groups. In addition to the short term impacts, which have been experienced, different and greater impacts, are felt by many water users. The impacts are manifested in conditions of significantly reduced water availability and require a broader response. The response must not only accommodate the reduced water availability but establish a mechanism for addressing the coming period of time during which surplus precipitation is required to balance the existing shortage. Reduced usage at this point serves the dual purpose of aiding the ability of the resource to rebound and bracing for the potential of long term drought.

c. Long Term Drought - (over 9 months).

Extended drought, although rare, is the phenomenon, which has severe impacts on the entire range of water uses. It requires coordinated response to assure that high priority water needs can be met. The months leading up to this point have offered the opportunity to implement contingency plans. Reduced water availability for all uses exists and requires demand reduction. Long term drought is additionally persistent because of the need for extended surplus precipitation to restore normal hydrologic conditions.

4. EVALUATION OF DROUGHT IMPACT LEVELS

The following approaches are presented to assist the drought management team in determining the suitability of declaring a specific drought level and appropriate response.

a. Precipitation

Precipitation data is obtained from the National Weather Service of the National Oceanic and Atmospheric Agency. Data can be evaluated by specific county or by groups of counties associated with drought management areas. Monthly total precipitation in inches is the basic unit of measurement.

LEVEL I.	Alert	(4 mos 65% or less)
	Four month cumulative precipitation less than 65% of normal for the period (March 1989)	
LEVEL 2	Warning	(6 mos variable)
	After 6 months based upon measured impacts and conditions	
LEVEL 3	Emergency	(12 mos 75% or less)
	Twelve month cumulative precipitation less than 75% of normal for the period (1964-65)	
LEVEL 4	Disaster	(not quantified)

b. Stream Flow

Stream flow data is obtained from the U.S. Geological Survey of the U.S. Dept. of Interior. Data is available for numerous gages however the following gages have been selected as indicators. Monthly mean streamflow in cubic feet per second is the basic unit of measurement.

The following stations representing generally unregulated rivers of significant size and statewide distribution are considered appropriate for evaluation by the DMT. These rivers are shown on a statewide map in the Appendix.

Lamprey River at Newmarket
Souhegan River at Merrimack
Soucook River at Concord
Ashuelot River at Hinsdale
Pemigewasset River at Plymouth
Upper Ammonoosic River at Groveton

LEVEL 1	Alert	(3 mos 65%)
	Three consecutive months where the mean flow for each month was less than 65% of the normal mean flow.	
LEVEL 2	Warning	(6 mos) (not quantified)
LEVEL 3	Emergency	(not quantified)
LEVEL 4	Disaster	(not quantified)

c. Soil Moisture

Soil Moisture data is assembled by the National Weather Service and is compiled into the Palmer Drought Severity Index. The Palmer index is calculated for two regions of N.H., northern and southern.

The following index values have been assigned to drought stages consistent with the New York State plan.

LEVEL	1	Alert	1.00 to 1.99
LEVEL	2	Warning	2.00 to 2.99
LEVEL	3	Emergency	3.00 to 3.99
LEVEL	4	Disaster	over 4.00

d. Groundwater Levels

Groundwater data is obtained from both the U.S. Geological Survey and certain public water suppliers. Due to the limited amount of historic data available, groundwater levels will be used to confirm trends indicated by other parameters and to measure the degree of recovery following extended drought.

Measurements indicate in what percentile of recorded values a present reading belongs. The lowest 25th percentile has been the historic reference for below normal.

e. Forest Moisture

Both the N.H. Dept. of Resources and Economic Development, Division of Forests and Lands and the U.S. Dept. of Agriculture, Forest Service monitor forest moisture and forest fire danger. The procedures established and maintained by these organizations will continue and be considered an integral part of the plan. N.H. DRED presently has a system with five fire hazard classes and four zones of the state.

f. Reservoir Levels

Reservoir levels are managed for one or more specific purposes. Measurement of reservoir levels is therefore an assessment of the management strategy as much as it is an assessment of hydrologic conditions. The larger lakes of N.H. are managed for both lake recreation and downstream flow management. Decreased water availability affects both interests. The distribution of the impact between interests depends upon legal constraints to the mode of operation.

Public water supply reservoirs have a single primary purpose and a demand, which can be adjusted according to the severity of a potential shortage. The following scheme applies to public water supply reservoirs but also has transfer value to those water suppliers with groundwater sources.

LEVEL 1 Alert (90 day buffer 85% of normal inflow)
If inflow over the next 90 days is 85% of the monthly normals and the supply cannot meet normal demand for the period (This concept was discussed but specific limits not endorsed by the Task Force).

LEVEL 2 Warning (Supply = demand)
The existing amount of water in storage plus normal expected inflow is adequate to meet but does not exceed maximum projected demand for the next 60 days.

LEVEL 3 Emergency (Supply < demand)
The existing amount of water plus normal expected inflow is not adequate to meet normal projected demand for the next 60 days.

LEVEL 4 Disaster

NOTE: The concept of source reliability over a 30, 60 or 90 day planning period based upon normal or below normal inflow was discussed and endorsed by the Task Force.

However, specific lengths of time, projected inflow amounts and demand projections were not established. These limits were viewed as administrative decisions to be made at the highest levels of government or made by the individual water supplier. The limits indicated above are guidance more than thresholds.

IV. RESPONSE

Response is the heart of the drought management plan. It is the means by which various water users adjust their behavior to accommodate reduced water availability. Variability in response exists by water use group and according to the magnitude and location of the drought.

Several members of the task force suggested the benefits of having the governor designate an individual with direct authority to make command decisions under emergency powers provisions on the part of the state. This was considered important due to the potential for the drought management team being unable to reach consensus. Also, suspension of various permit requirements or administrative orders may be necessary to accommodate severe conditions in a timely manner. Not all task force members agreed with the need for this authority to be vested in one individual.

In general, the level of response corresponds with the stage of the drought.

LEVEL 1 Alert
At this level a detailed assessment of hydrologic conditions relative to a specific source or use should be conducted if not already done. This assessment should include a projection into the future to determine the potential need for voluntary or mandatory action.

LEVEL 2 Warning
Voluntary water conservation measures are initiated to prevent serious shortages. Investigation of potential source augmentation may be undertaken. The need for mandatory action is evaluated.

LEVEL 3 Emergency
Mandatory water conservation measures are implemented. Generally these conservation measures relate to nonessential water use.

LEVEL 4 Disaster
At this point, water use restrictions may be imposed which have significant economic implications. Emergency powers of the Governor may be exercised to mitigate severe local impacts.

The impacts of severity and duration on drought magnitude are discussed in the Detection/Monitoring section for this plan. General guidance and oversight are provided by the Drought Management Team (DMT). This includes information on hydrologic conditions1 the availability of state, federal and local resources and coordination of response by the various water use groups. The DMT might be considered the brain of drought response but the water use groups are the arms and the particular users are the fingers, which put the pieces in place. Each individual user has a fundamental responsibility for his or her actions under various conditions. The water use groups are listed below:

1. Public Water Suppliers
2. Municipal Waste Discharges
3. Agriculture
4. Industry
5. Power Production
6. Recreation

This section is divided into water use groups, parties responsible for certain actions within each group and the range of actions, which are available and appropriate.

1. PUBLIC WATER SUPPLIERS

This group consists of both large and small organizations, which provide drinking water and are regulated under the public drinking water program. Municipalities and private corporations which provide water from surface and/or groundwater sources have a fundamental role to play in drought response. A representative of this group will be part of the Drought Management Team for coordination and oversight purposes. Each system should have its own monitoring and response plan tailored to local conditions. The New Hampshire Department of Environmental Services, Water Supply Engineering Bureau has a significant role in enforcing the requirement that a local drought contingency plan exist for each water system. The New Hampshire Public Utilities Commission has significant jurisdiction over the private water suppliers.

Participants

a. Municipal Water Suppliers
b. Private Water Companies
c. Small Public Systems
d. New Hampshire Department of Environmental Services
e. New Hampshire Public Utilities Commission

Potential Actions

A range in potential actions exists and is presented below. The actual response taken is dependent upon the severity and duration of the drought and the capabilities of the particular water system. The water supplier will develop a particular combination of actions appropriate to local conditions.

a. Leak Repair
b. Non-essential water use restrictions
c. Pressure reductions
d. Voluntary water conservation
e. Mandatory water conservation
f. Emergency source enhancement
g. Interconnection
h. Major user restrictions
i. Emergency rate structures
j. Source blending

2. MUNICIPAL WASTE WATER DISCHARGERS

These facilities have a significant impact upon hydrologic systems in drought conditions. The water discharged may constitute a considerable part of the stream flow, which could be relied upon by a downstream water user. During drought conditions, the release of treated effluent can have a more significant adverse effect upon water quality than would normally be experienced.

Participants

a. Municipal Waste Water Dischargers
b. New Hampshire Department of Environmental Services
c. U.S. Environmental Protection Agency

Potential Actions

Although these facilities have little control over the amount of inflow, the method and extent of treatment can have a bearing on the impacts to the receiving stream. Recycled wastewater could be used in lieu of fresh water in certain circumstances to reduce the demand for potable water. Increased purification and/or disinfection might be feasible to reduce water quality degradation in the receiving stream. Temporary storage of effluent coupled with accelerated discharge during runoff periods may be feasible to maintain optimum water quality. A close examination of the particular situation is essential to assess the feasibility and impacts of potential actions.

a. Use of recycled effluent in treatment plant operation
b. Increased treatment
c. Temporary storage

3. AGRICULTURE

Agriculture in New Hampshire is as diverse as the state's topography. Water is used for irrigation of food crops, nursery products, and turf. Irrigation for golf courses is widespread. Additional non-irrigation water use exists in the dairy industry and for frost control in the fruit business. In addition to farmers, the Cooperative Extension Service the Soil Conservation Districts and the Department of Agriculture can play vital roles in drought management.

Participants

a. Farmers
b. Cooperative Extension Service
c. New Hampshire Department of Agriculture
d. Soil Conservation Districts

Potential Actions

The range of potential actions depends upon the crop being grown and the flexibility the business has to adjust to changing hydrologic conditions. Irrigation is dependent upon crop needs and hydrologic conditions. Increased irrigation coupled with decreased water-availability can compound adverse impacts. Altered crop rotations may reduce water demand. Decreased plant vigor may be tolerable in certain circumstances. Irrigation methods could be altered to make the process more efficient.

a. changes in irrigation methods and amounts
b. change in crops

4. INDUSTRY

Industrial water use is highly variable and dependent upon the process involved. Some industrial use is consumptive in that water is lost from the basin through evaporation or export. Most industrial water use is either partially consumptive or non- consumptive. Due to the wide range of industrial uses, specific analysis is needed in assessing potential responses.

Participants

a. Heavy Industry
b. Light Industry
c. Food Processing
d. Mining

Potential Actions

Many possibilities exist for water use reduction. The potential is highly dependent upon the extent of water conservation instituted previously. Principle areas of action include leak repair, non-essential use reduction, process modification and source augmentation. The options for water suppliers and waste water treatment plants may have some carry over value to this water use group.

a. Process modification
b. Leak repair
c. Non-essential use reduction
d. Source augmentation

5. POWER PRODUCTION

All forms of commercial power production are highly dependent upon water and limitations on water availability will reduce power production. (Solar and wind excluded) Hydropower production is a direct result of river flow. Fossil fuel, biomass and nuclear power production require water for steam production and cooling water.

Participants

a. Hydropower Producers
b. Fossil fuel Power Producers
c. Biomass Power Producers

Potential Actions

There is a continuing debate over the most appropriate course of action in a drought when the two options are increased water availability at reduced quality or reduced availability at improved quality. In power production, cooling ponds and towers dissipate excess heat which would otherwise be returned to a river or stream. This results in a lesser quantity of water being returned. This dilemma can only be resolved at the highest level of federal and state regulation. Should water quality be degraded below "acceptable" levels in order to assure an adequate volume of flow at a downstream location? The answer to this question will provide direction for possible courses of action.

a. Decreased evaporative losses
b. Increased evaporative losses

6. RECREATION

New Hampshire's second largest industry is tourism. Outdoor recreation is essential not only for the tourist industry but for the one million residents who enjoy the scenic beauty and recreational opportunities our lakes, rivers and streams provide. Generally speaking recreation will continue regardless of hydrologic conditions however there are certain exceptions where impacts are noticeable. Lack of natural snow reduces alpine skiing opportunities. Snowmaking for alpine skiing can be a significant demand for water and can have adverse impacts if the water is drawn from a small river or stream. The risk of forest fires is greatly increased during droughts, which limits the appropriateness of camping and campfires. Management of water levels in the State's major lakes impacts recreation on the lakes and rivers, which they feed. Seasonal changes in storage are induced to provide multiple benefits. These changes are based on an average water year so that when a drought occurs, water levels may remain low through the recreational season. Water quality at non-pool swimming areas may become degraded due to less flow, increased temperature or greater usage. Increased sampling is required to evaluate potential adverse health effects and trigger advisories or beach closures.

Participants

a. Citizens
b. Ski area operators
c. N.H. Department of Resource and Economic Development
d. N.H. Department of Environmental Services - Water Resource Division
e. U.S. Department of Agriculture - Forest Service
f. N.H. Fish and Game Department
g. N.H. Department of Health - Division of Public Health Services

Potential Actions

Actions can range from reduced skiing in the winter to closing the woods to camping in the summer and fall. Severe drought could result in poor water quality in rivers and streams, which could necessitate health advisories. Changes in stream flow resulting from altered regulation of surface water body discharges should be expected.

a. Limit camping
b. Health advisories for rivers
c. Reduced snowmaking
d. Increased monitoring for forest fires
e. Altered management of lake levels

V. CONCLUSIONS

In the inevitable event of the next drought, the existence of this drought management plan will avoid unnecessary and wasteful crisis planning. By establishing a detection and monitoring plan, the state will have the information at hand to determine if and when to initiate a response and when those special responses are no longer necessary. The administration section of this plan will assure that those agencies and entities with valuable input will be involved in the decision process. The response section lists those people responsible for affecting water use patterns and the range of possible actions available to them.

The real benefit is that many of the decisions, which are generic in nature, will already have been made. This allows those who are responsible to focus their efforts on particular situations, which may demand a unique response. The more decisions, which can be made in advance of a crisis, the easier it is to make the remaining decisions to see the state through the crisis.

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APPENDIX C

DROUGHT MANAGEMENT AREAS

Two scenarios exist for dividing the state into drought management areas. The first approach is based upon hydrologic boundaries and a generalized understanding of weather zones. This includes the coastal lowlands, southern interior, southwestern and northern sections. The areas are expressed as the drainage areas of the Lamprey, Exeter, Oyster, Salmon Falls and Coastal Rivers; the Merrimack River Basin; the southern Connecticut River Basin; and the northern drainages.

Upon closer scrutiny it became evident that these regions could be generally respected and additional benefits gained if the state were divided along county lines. The obvious benefits of this second approach are that individual towns would not be divided into different drought management areas and that institutions exist with coincident boundaries that can greatly assist in drought response. These institutions include county governments, regional planning agencies and Soil Conservation Districts. The following groupings of counties are proposed as drought management areas.

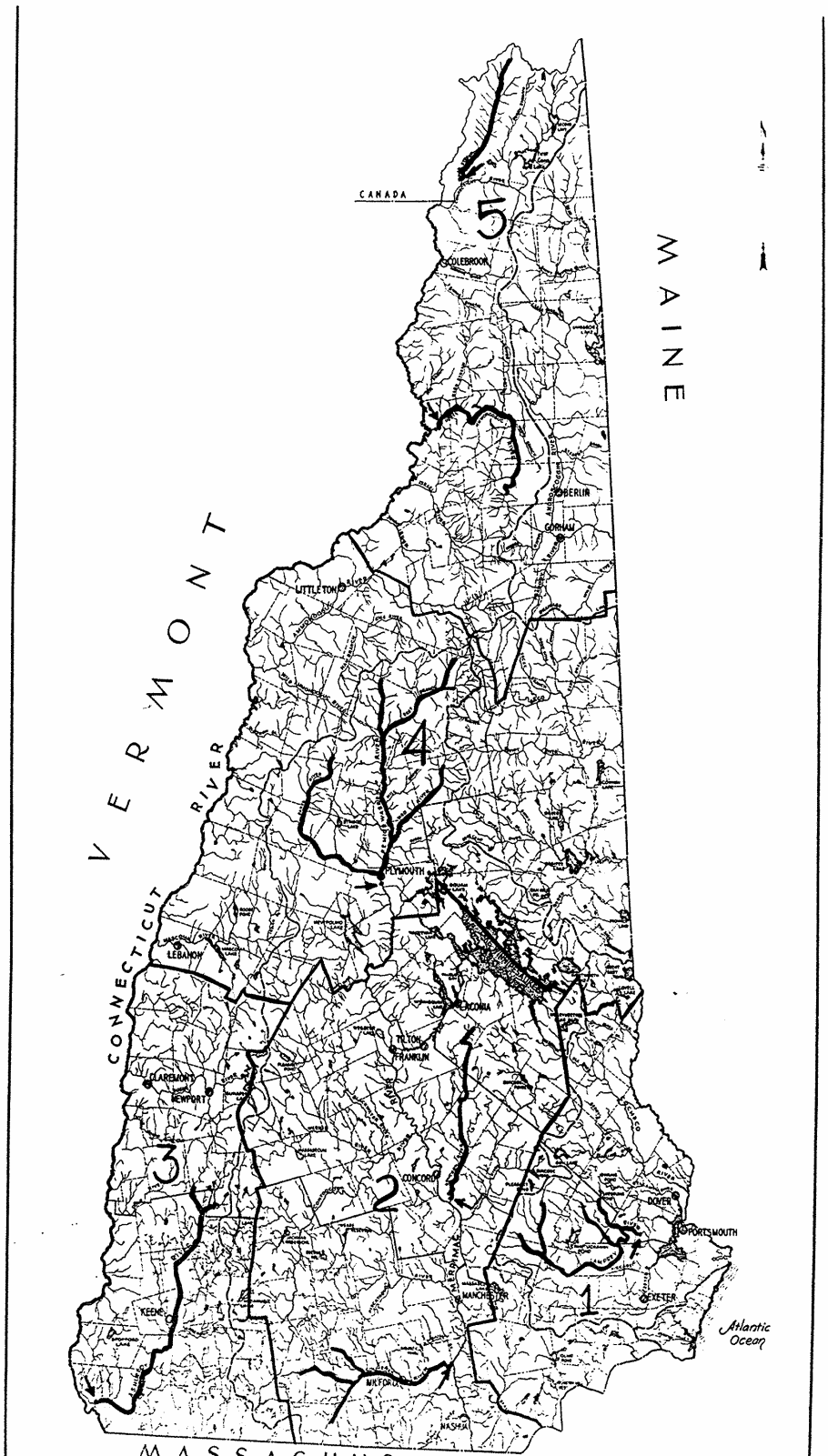
1) Coastal Drainages
   - Strafford County
   - Rockingham County

2) Southern Interior
   - Hillsborough County
   - Merrimack County
   - Belknap County

3) South Western
   - Cheshire County
   - Sullivan County

4) White Mountain
   - Grafton County
   - Carroll County

5) North Country
   - Coos County



DROUGHT MANAGEMENT AREAS

INDICATOR STREAM FLOW GAGES

THE DROUGHT SEVERITY (LONG-TERM, PALMER) INDEX

The Drought Severity, or Palmer, Index is an index of meteorological drought (or moisture excess) and indicates prolonged abnormal conditions affecting water-sensitive economics. The index usually ranges from about -6 to +6, with negative values denoting dry spells and positive values, wet spells of weather. The equations for the index were derived from monthly average data and based on the concept of a balance between moisture supply and demand (Palmer, 1965). The equations have been modified to compute the index on a weekly basis for publication in the Weekly Weather and Crop Bulletin. Input data consists of weekly temperature averages and precipitation totals for 350 climate divisions in the United States and Puerto Rico.

The index is a sum of the current moisture anomaly and a portion of the previous index to include the effect of the duration of the drought or wet spell. The moisture anomaly is the product of a climate weighting factor and the moisture departure. The weighting factor allows the index to have a reasonably comparable significance for different locations and time of year. An index value for a division in Florida would have the same local implication as a similar value in a more arid division in western Kansas. The moisture departure is the difference of water supply and demand. Supply is precipitation and stored soil moisture, and demand is the potential evapotranspiration, the amount needed to recharge the soil, and runoff needed to keep the rivers, lakes, and reservoirs at a normal level. The runoff and soil recharge and loss are computed by keeping a hydrologic accounting of moisture storage in two soil layers. The surface layer can store one inch, while the available capacity in the underlying layer depends on the soil characteristics of the division being measured. Potential evapotranspiration is dervied from Thornthwaite's method (1948).

The index is measured from the start of a wet or dry spell and is sometimes ambigious until a weather spell is established. A week of normal or better rainfall is welcome in an area that has experienced a long drought, but may be only a brief respite and not the end of the drought. Once the weather spell is established (by computing a 100 percent "probability" that an opposite spell has ended), the final value is assigned. To make the program have a real-time significance, a value is assigned based on a greater than 50 percent "probability" that the opposite weather spell has ended. This is not entirely satisfactory, but it does allow the index to have a value when there is a doubt that it should be positive or negative.

One aspect that should be noted is that the demand part of the computations includes three parameters—potential evapotranspiration, recharge of soil moisture, and runoff—any one of which may produce negative values. If only enough rain fell to satisfy the expected evapotranspiration but not enough to supply the recharge and runoff, then a negative index would result. If such an odd situation continued, agriculture would progress at a normal pace but a worsening drought would be indicated. Shallow wells and springs would dry and the levels of rivers, lakes, and reservoirs would fall. Serious economic stress to the livestock trade, industries, and cities would eventually result. Then if rainfall fell below the minimum needed for agriculture, crops would suffer drastic and rapid decline because there would be no reserve water in the soil. Such a situation, to some extent, occurred during the Northeast drought in the mid-1960's when New York City almost ran out of water.

A detailed explanation and examination of the index is given by Alley (1984). Both Alley and Karl (1983) address the sensitivity of the index and list some limitations.

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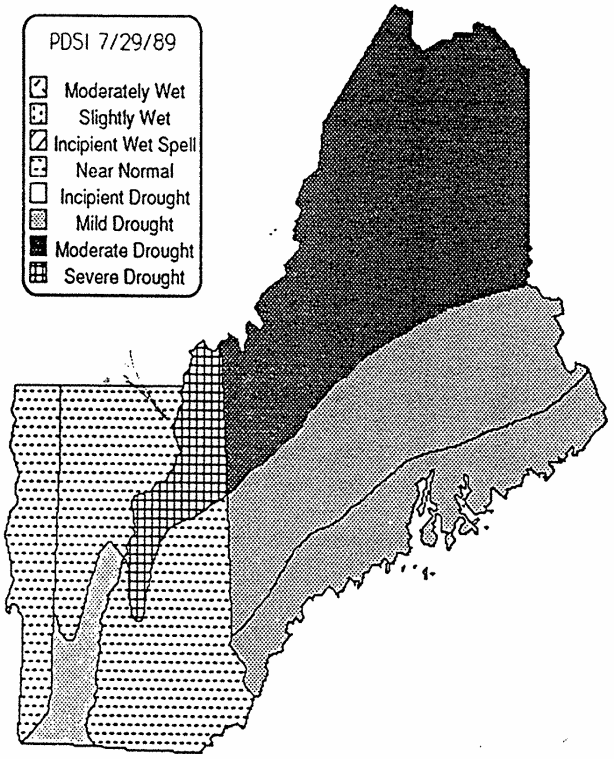
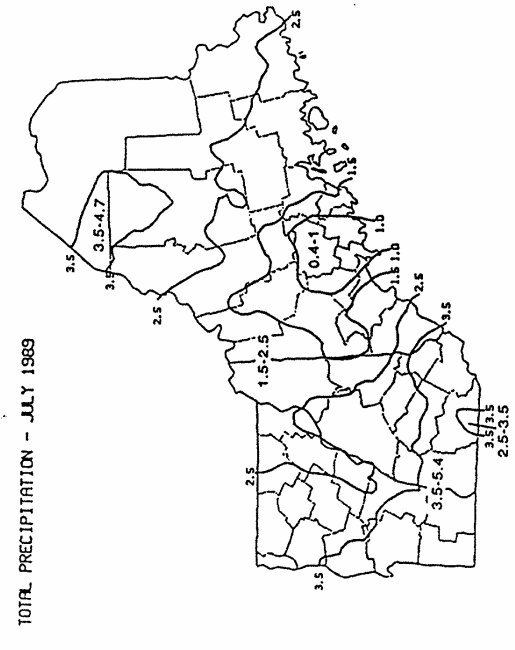
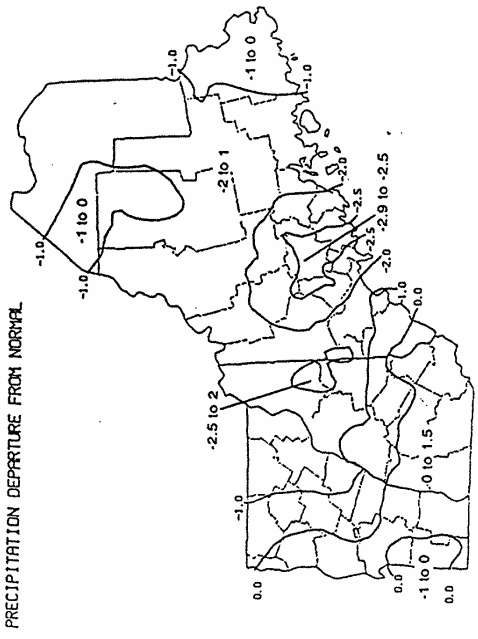
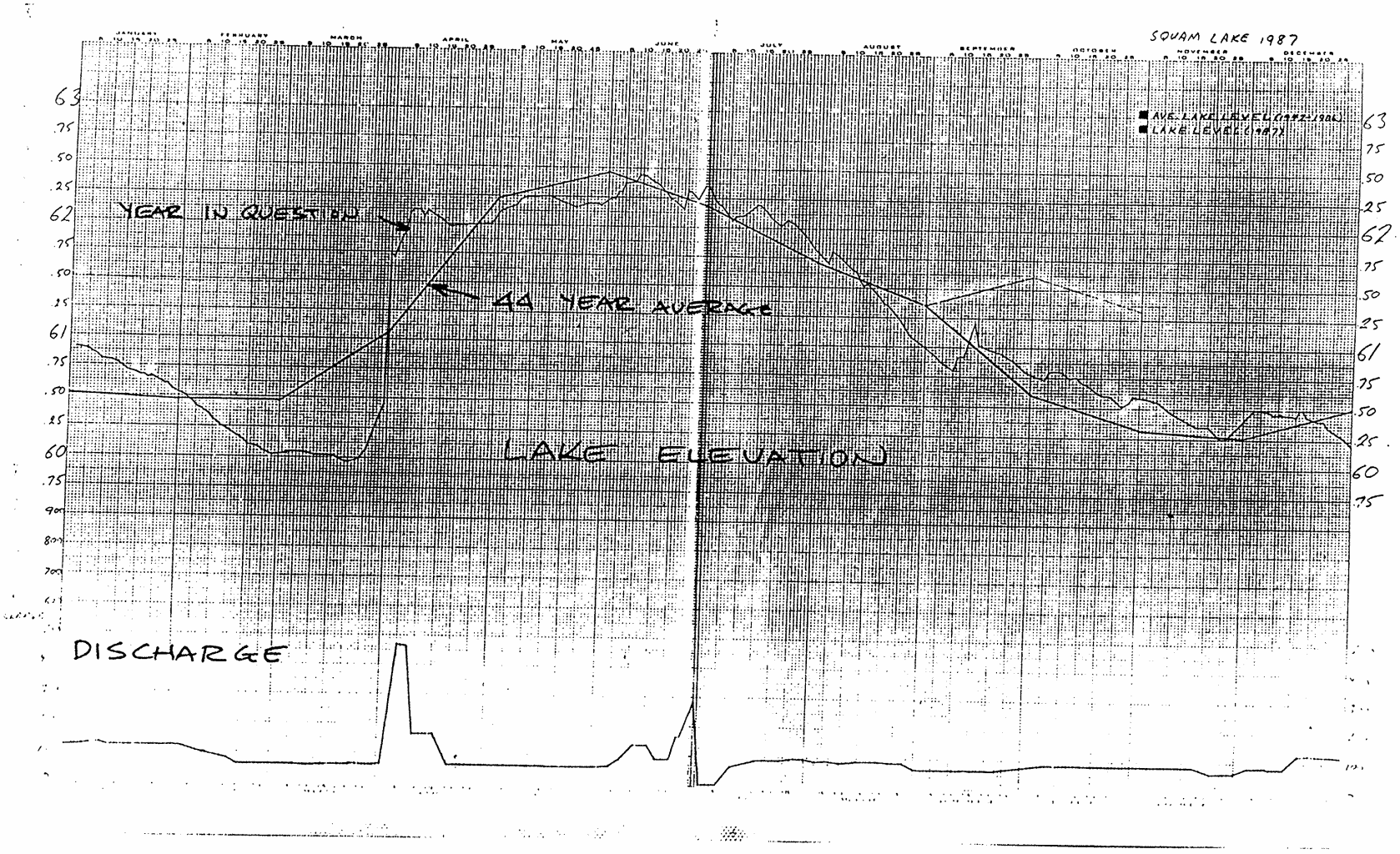






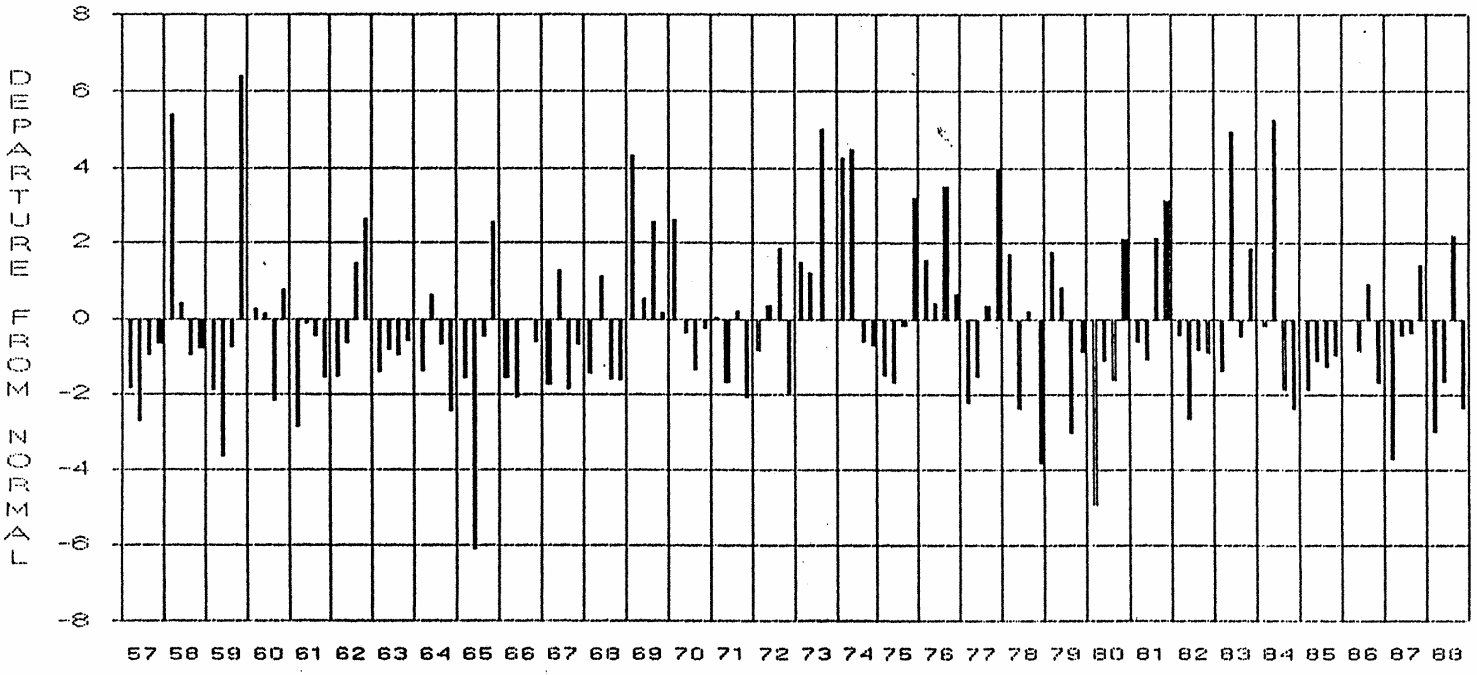
LAKE LEVEL OPERATING CURVE



NORMAL PRECIPITATION
NEW HAMPSHIRE
(1951-1980)

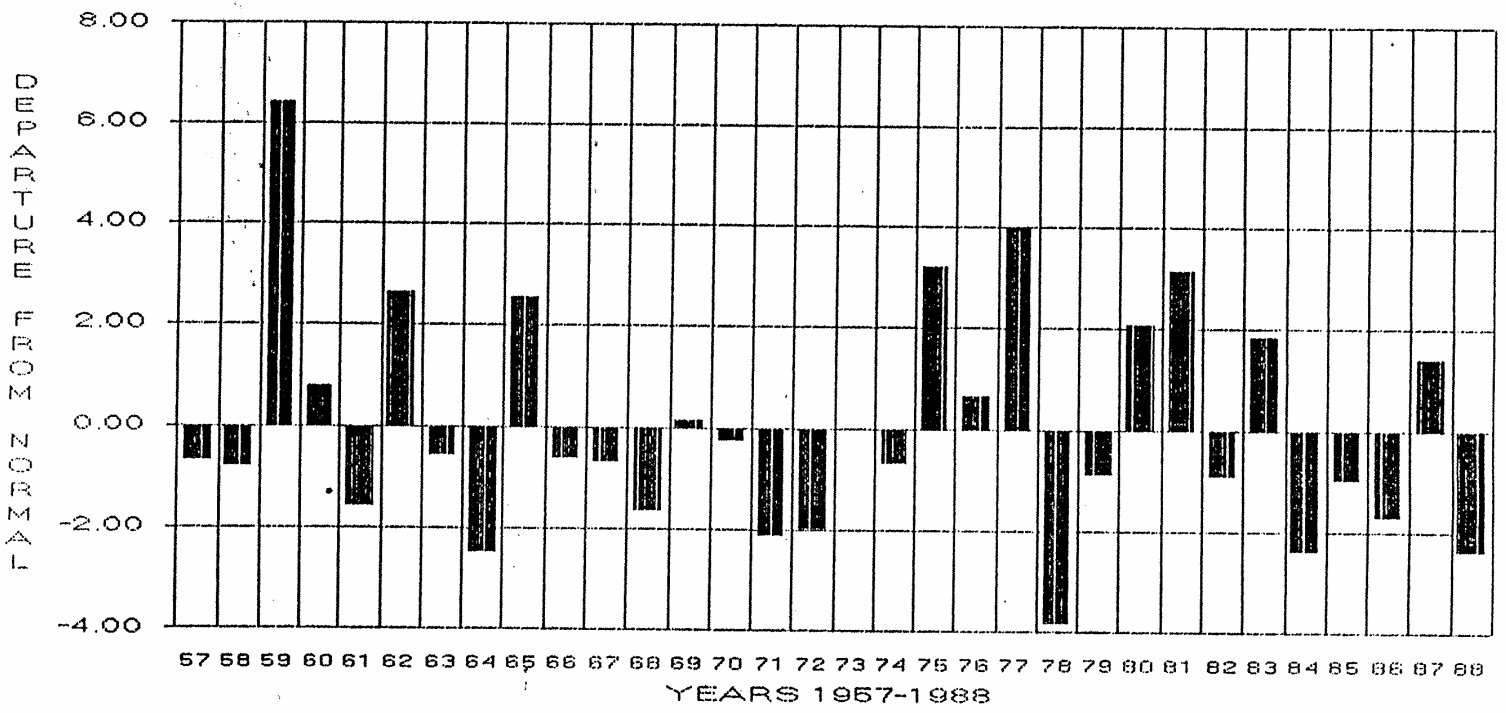
MQNTII	NORTHERN DIVISION	SOUTHERN DIVISION
January	2.79	3.27
February	2.59	2.94
March	2.94	3.46
April	3.17	3.43
May	3.50	3.52
June	4.09	3.27
July	4.09	3.39
August	3.99	3.44
September	3.59	3.46
October	3.60	3.55
November	3.79	4.08
December	3.58	3.94
ANNUAL	41.72	41.75

ABSOLUTE DEPARTURE FROM NORMAL PRECIPITATION (IN) BY SEASON : NEW HAMPSHIRE - NORTHERN DIVISION

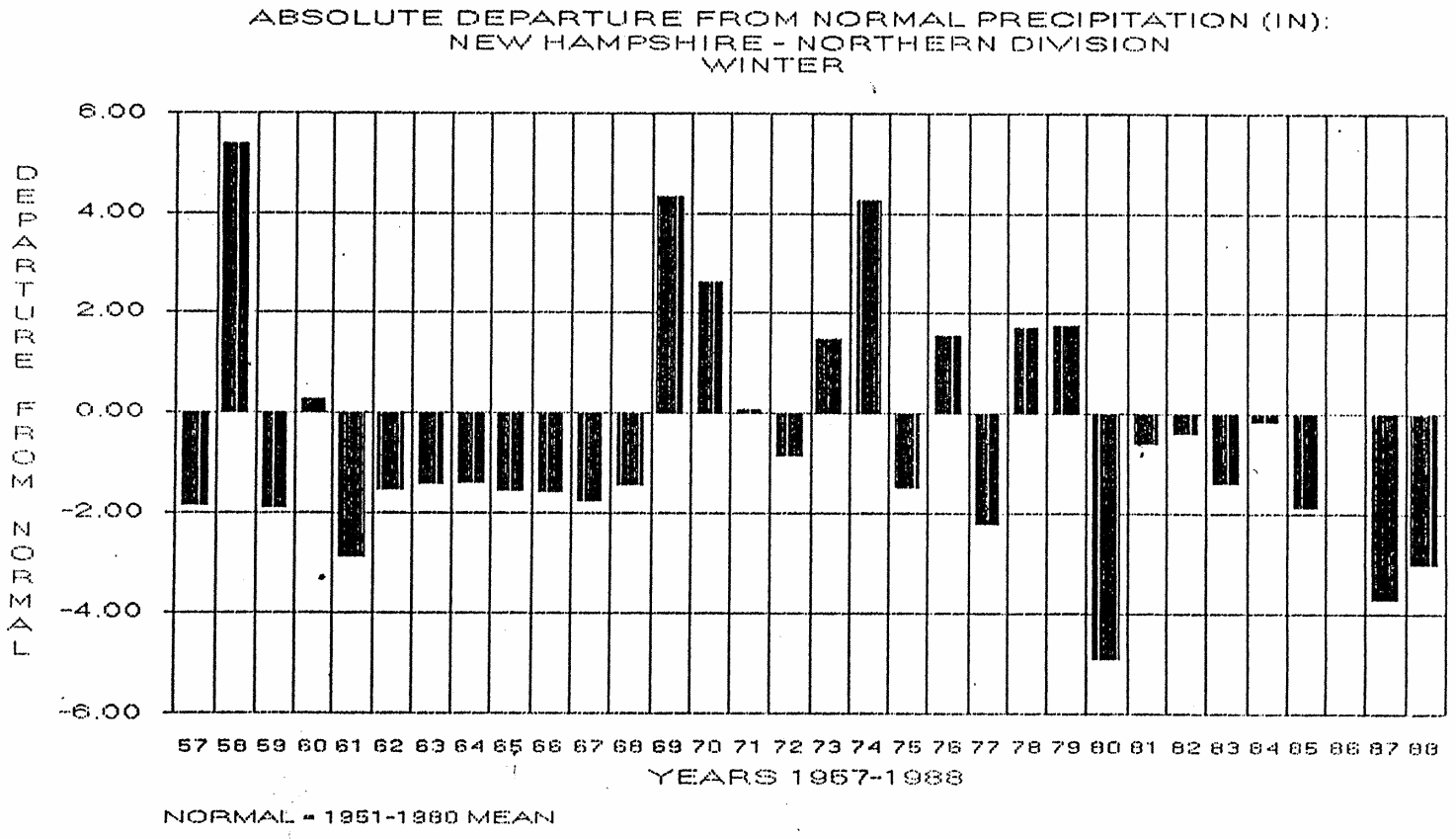


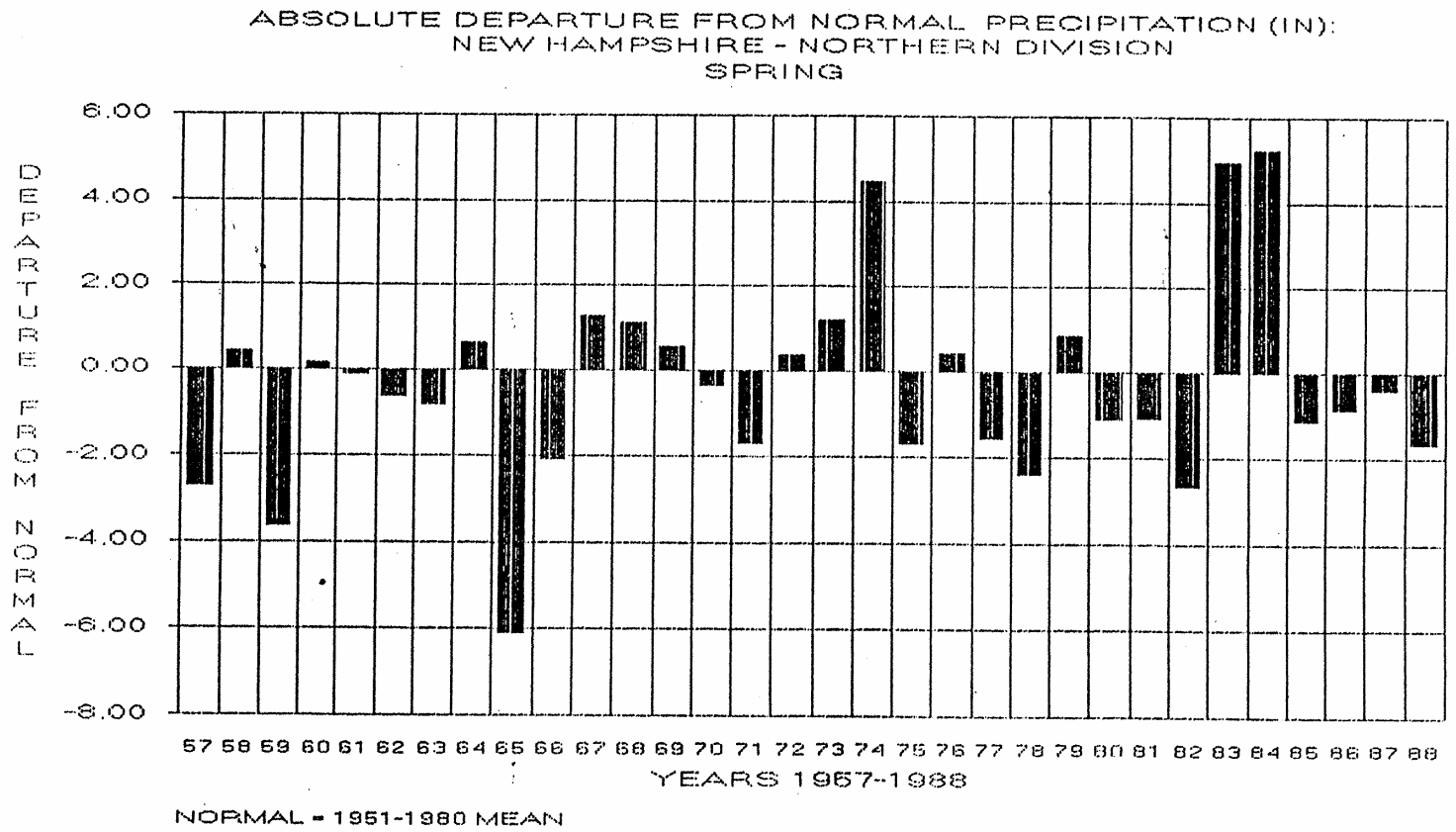
FOR EACH YEAR, THE BARS FROM LEFT TO RIGHT REPRESENT WINTER, SPRING, SUMMER AND FALL RESPECTIVELY

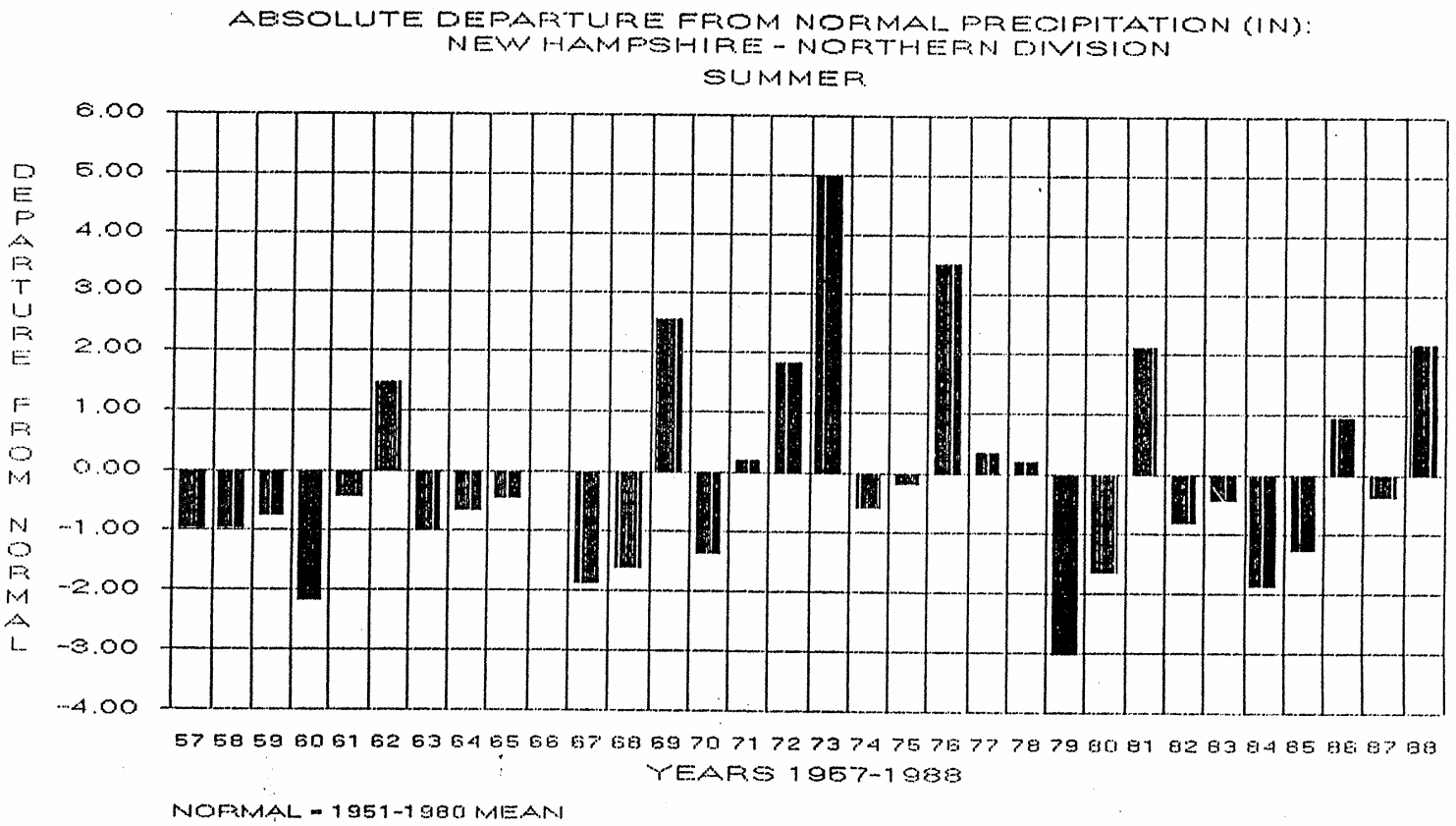
ABSOLUTE DEPARTURE FROM NORMAL PRECIPITATION (IN):
NEW HAMPSHIRE - NORTHERN DIVISION
FALL



NORMAL = 1951-1980 MEAN


ABSOLUTE DEPARTURE FROM NORMAL PRECIPITATION (IN):
NEW HAMPSHIRE - NORTHERN DIVISION
WINTER
DEPARTURE FROM NORMAL
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88
YEARS 1957-1988
NORMAL = 1951-1980 MEAN

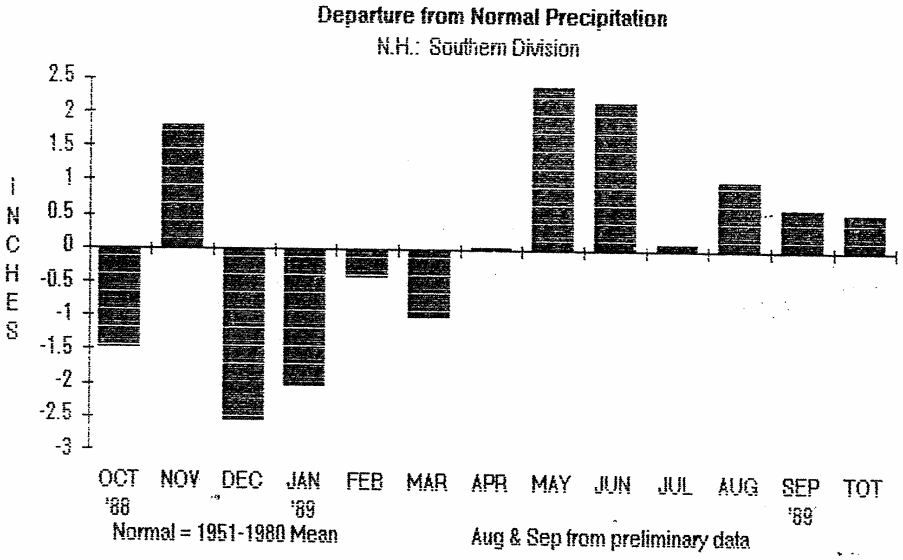

ABSOLUTE DEPARTURE FROM NORMAL PRECIPITATION (IN):
NEW HAMPSHIRE - NORTHERN DIVISION
SPRING
DEPARTURE FROM NORMAL
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88
YEARS 1957-1988
NORMAL = 1951-1980 MEAN

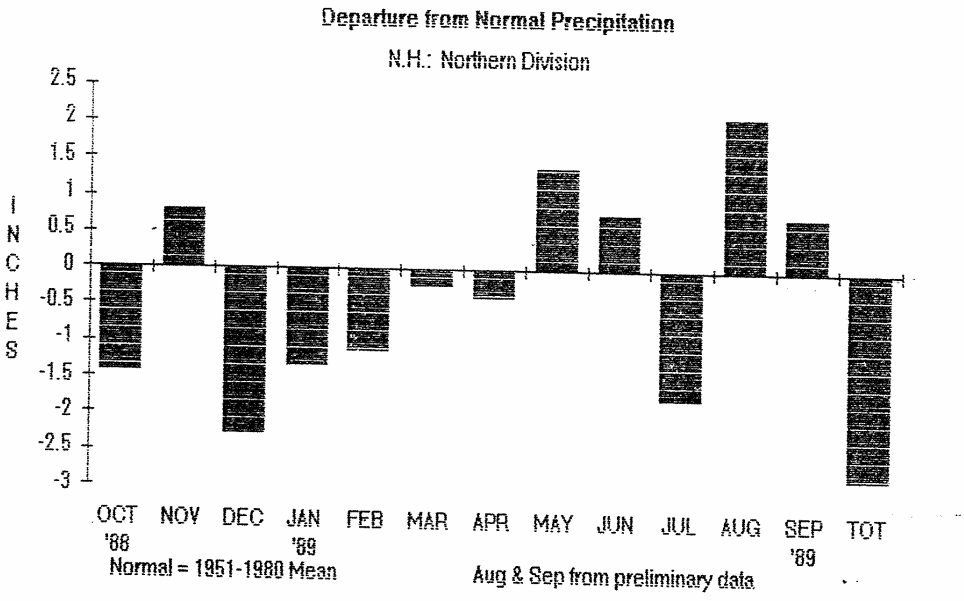

ABSOLUTE DEPARTURE FROM NORMAL PRECIPITATION (IN):
NEW HAMPSHIRE - NORTHERN DIVISION
SUMMER
DEPARTURE FROM NORMAL
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88
YEARS 1957-1988
NORMAL = 1951-1980 MEAN

NEW HAMPSHIRE:
DEPARTURE FROM NORMAL PRECIPITATION
(INCHES)

MONTH	NORTHERN DIVISION	SOUTHERN DIVISION
OCT '88	-1.44	-1.5
NOV	0.79	1.8
DEC	-2.3	-2.58
JAN '89	-1.35	-2.04
FEB	-1.13	-0.43
MARCH	-0.24	-1.02
APRIL	-0.38	0.03
MAY	1.37	2.4
JUNE	0.78	2.17
JULY	-1.77	0.09
AUG	2.08	1.03
SEPT '89	0.75	0.62
TOT DEPART	-2.84	0.57

NORMAL= 1951-1980 MEAN
AUG & SEPT FROM PRELIMINARY DATA


Departure from Normal Precipitation
N.H.: Southern Division
INCHES
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
OCT '88
NOV
DEC
JAN '89
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP '89
TOT
Normal = 1951-1980 Mean
Aug & Sep from preliminary data


Departure from Normal Precipitation
N.H.: Northern Division
INCHES
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
OCT '88
NOV
DEC
JAN '89
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP '89
TOT
Normal = 1951-1980 Mean
Aug & Sep from preliminary data

APPENDIX I

Appendix I Exceedence Probability Analysis of Drought in New Hampshire

Drought Events Identified from Palmer Hydrological Drought Indices, 1895-1984 (Only, events of 3 months or more are included). The data presented below was compiled from monthly data gathered by the National Weather Service from 1895 through 1984 by Chris Nash as part of his graduate studies in water resources management at the University of N.H.

Southern New Hampshire

Year	Drought events (in months)	Rank	Exceedence Probability	Return Period (Years)
1966	30	1	0.011	93.0
1942	22	2	0.022	46.5
1911	20	3	0.032	31.0
1957	11	4	0.043	23.2
1907	10	5	0.054	18.6
1950	10	6	0.065	15.5
1940	10	7	0.075	13.3
1981	9	8	0.086	11.6
1951	9	9	0.097	10.3
1914	8	10	0.108	9.3
1963	7	11	0.118	8.5
1948	7	12	0.129	7.8
1931	6	13	0.140	7.2
1900	6	14	0.151	6.6
1909	5	15	0.161	6.2
1954	5	16	0.172	5.8
1918	5	17	0.183	5.5
1915	4	18	0.194	5.2
1915	4	19	0.204	4.9
1978	4	20	0.215	4.7
1905	4	21	0.226	4.4
1967	4	22	0.237	4.2
1980	3	23	0.247	4.0
1896	3	24	0.258	3.9
1909	3	25	0.269	3.7
1909	3	26	0.280	3.6
1959	3	27	0.290	3.4
1932	3	28	0.301	3.3

Northern New Hampshire

Year	Drought events (in months)	Rank	Exceedence Probability	Return Period (Years)
1950	30	1	0.011	93.0
1981	20	2	0.022	46.5
1942	11	3	0.032	31.0
1983	8	4	0.043	23.2
1965	7	5	0.054	18.6
1959	7	6	0.065	15.5
1931	7	7	0.075	13.3
1954	6	8	0.086	11.6
1914	6	9	0.097	10.3
1957	5	10	0.108	9.3
1978	4	11	0.118	8.5
1977	4	12	0.129	7.8
1966	4	13	0.140	7.2
1962	4	14	0.151	6.6
1957	4	15	0.161	6.2
1952	4	16	0.172	5.8
1942	4	17	0.183	5.5
1909	4	18	0.194	5.2
1981	3	19	0.204	4.9
1968	3	20	0.215	4.7
1961	3	21	0.226	4.4
1943	3	22	0.237	4.2
1915	3	23	0.247	4.0
1911	3	24	0.258	3.9